ІННОВАЦІЙНО-ІНВЕСТИЦІЙНІ ПРОЦЕСИ

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Kirova M.P.
PhD, Assistant Professor
University of Rousse, Rousse, Bulgaria

COMPARISON AND ASSESSMENT OF INNOVATION PROJECTS FOR ACHIEVING SUSTAINABLE DEVELOPMENT IN THE SMALL MANUFACTURING BUSINESS ENVIRONMENT

The paper presents a new model for sustainable development, requiring less resources and applicable to small companies. It is applied for typical manufacturing products made in small batches. Production diagrams and material flow calculations are presented. The results are found to be satisfactory in terms of the necessity to take the right decision for choosing sustainable products.

Key words: sustainable development, manufacturing, mathematical model, ecology

Introduction. The concept for sustainable development is not required by law to be implemented in nowadays business environment. If a company project meets the requirements of the appropriate national committees responsible for the environment protection, it is considered safe and can be started, though it may transfer the environmental problems in another area. For example, to eliminate smokes a company may consider to use electrical heating equipment, but how this electricity is produced it is not a subject of discussion, whether it comes from renewable or non-renewable sources.

There are different models trying to solve the environmental problems created by human activity: some concentrate on the transformation flows, some - on the economic aspects; some are trying to integrate transformation flows and economics using rather complicated mathematics [Apostolov: 2005, Bouman: 2000].

At present even the most sophisticated environmental models do not give accurate results and are applicable only in organizations with many resources. However most of the business entities can be determined as small and having limited resources to conduct environmental policy.

The model presented in this paper is based on the theory of life cycle assessment [Curran: 1996, Leontev: 1994] and compares and evaluates different innovative projects for achieving sustainable development in the small business manufacturing environment.

Research aim. The model uses material and energy flows presented by production diagrams and tables. The material flows include everything from the initial natural resources to utilizing the waste after the product is not used any more. The energy flows include all the necessary energy from the production of the initial resource to the utilization of the waste. The energy flows are converted into material flows traced back to the initial resources. In every stage of the flows transformation the model accounts for the environmental impact with real values.

The flows transformations are dimensioned in two directions. The first one goes from the quantity of the produced product, its usage and related consumptions up to the utilization of the waste after it is not used any more. The second goes in the opposite way – from the product to the resources, materials and energy up to the initial natural resources – ores, oil, etc.

The influence on the nature is expressed in terms of exhaustions and pollution.

To quantify the innovation, the transformations are done for the innovation and existing product with the same functions.

Methodology. The model is applied for selection of innovation projects of the American company Merit Gear Corporation® (www.meritgear.com). The subjects are two gear box covers. The gear box is used in drilling equipment mounted on a truck. The first cover is welded design. The second cover is made from a monolith metal steel plate. The following limitations are used for the selection of the alternative projects: the covers are manufactured in the environment of small specialized manufacturing company; the life cycle of the covers is 10 years, working two shifts, 6 days a week; the same materials and cutting conditions are used for the two covers, the parts are cut manually by oxy-acetylene cutting equipment; heat treatment is not considered because it is usually done together with the other part of the gear box; there is no size optimization of the steel plate cutting; the drawings are developed by Merit Gear Corporation® using SolidWorks® and may not represent the real configurations of the covers.

It is necessary to compare to what extent the two covers comply with the requirement for sustainable development. The production diagrams showing the material flows between 12 nodes are created (Fig. 1 and Fig. 2).

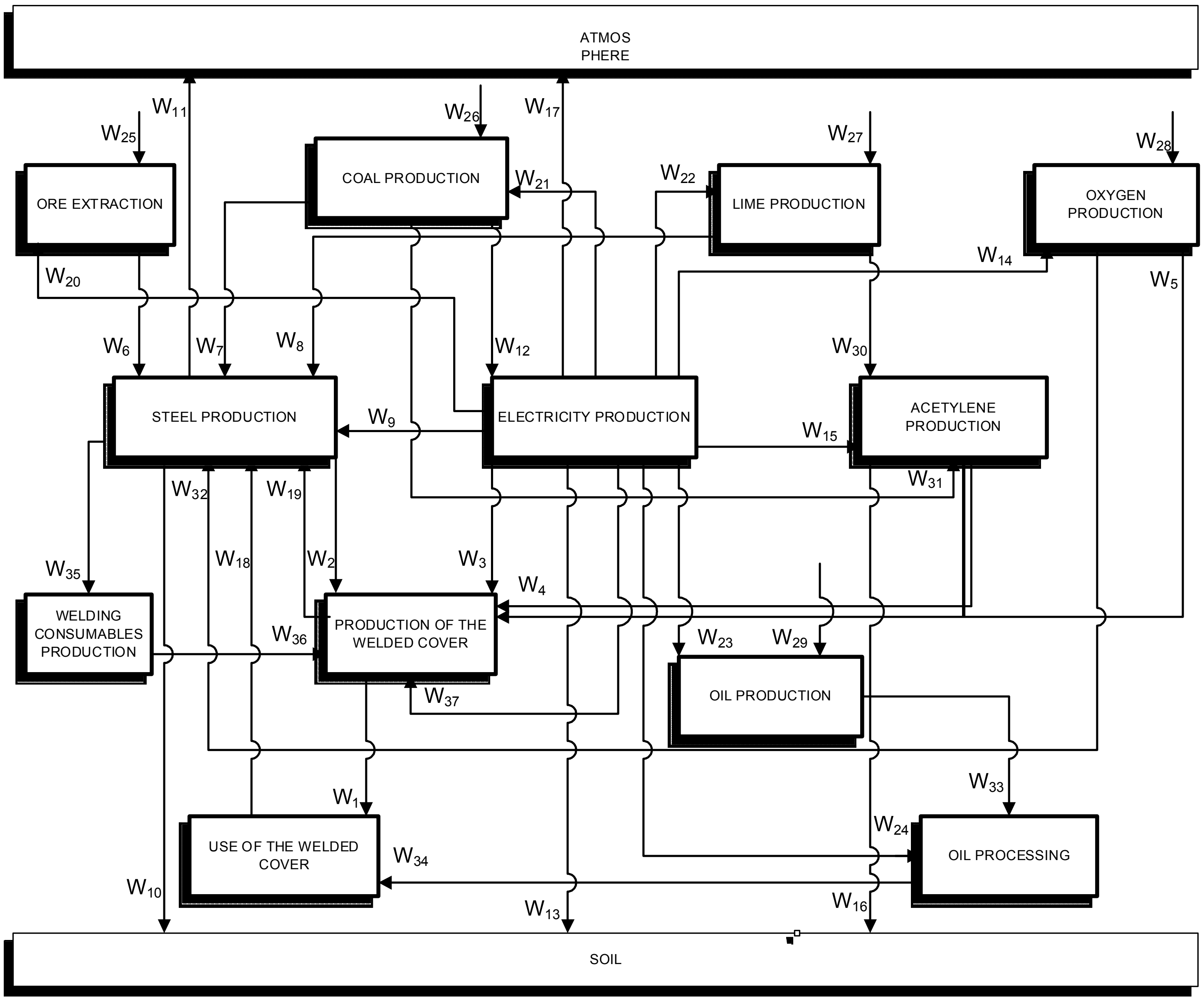

Fig. 1. **Production diagram of the welded cover**

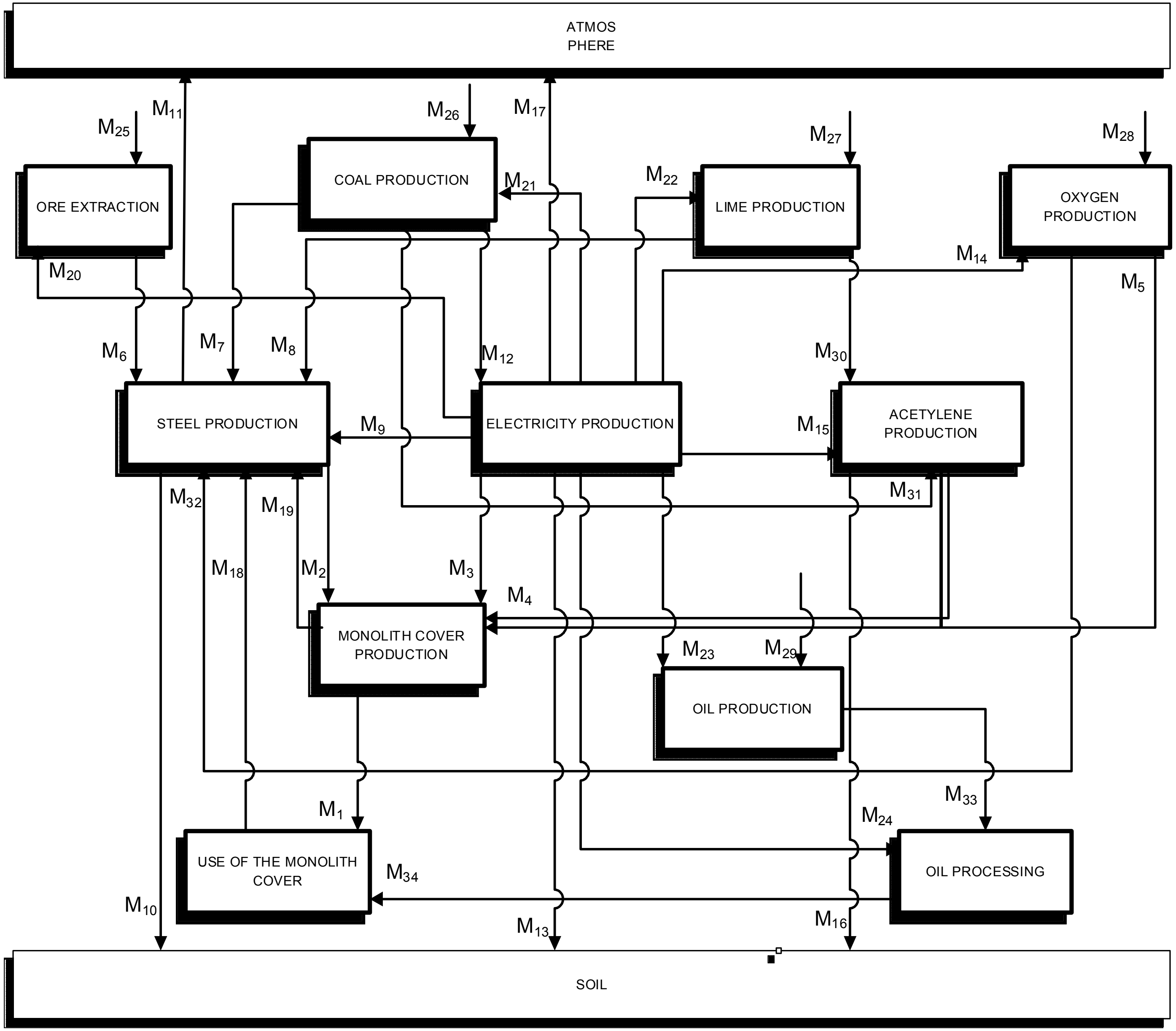

Fig. 2. **Production diagram of the monolith cover**

The following conventions are established: the input flows are determined with positive sign, and the output – with negative. The order for determining the flows is the following: it starts with quantities of the two produced covers which are represented with their weights; then are determined the flows of the used covers, the use of materials and energy for their production and the waist after recycling, the materials are moved to the corresponding production node and they reduce the quantities of the initial resources. To determine the influence of the innovation upon the environment, the flows from the covers production and usage are transformed into flows from the environment and into the environment, i.e. the life cycle is expanded to cover the full influence of the products on the environment. For this purpose on the basis of the diagrams of the flows (Fig. 1 and Fig. 2) are created Table 1 and Table 2, where the flows are shown with their numerical values.

The values of the materials flows are given in Table 1 and Table 2. The calculations of the quantity of materials, energy and waste used during the life cycle of the covers are based on formulas given in the popular mechanical engineering books and also data from the Environmental protection Agency (www.epa.gov) and The American Iron and Steel Institute (www.steel.org).

Several simplifications are accepted which do not reduce the accuracy of the calculations. It is not necessary to know exactly the origin of the resources – iron ore, oil, etc. because of the complex configuration on the world markets. No matter what statistical data is used it can not be completely accurate. When we deal with materials which can be recycled, the quantities of the initial resources are reduced to

extent where they can not compromise the result of the study, and the moment of recycling can not be tight to any specific manufacturer. That's why it is relevant to calculate the flows of the initial resources on the basis of available data, without detailed study of their processing. This simplification is possible because the purpose of the research is to compare the influence of the alternative innovations on the sustainable development which can be achieved in a satisfactory way by using average data. The labor and capital are excluded from the model, because they are considered to be equal in both cases.

The influence upon the environment goes in two directions: exhaustion of the natural resources iron ore, oil, etc and pollution of the atmosphere and soil from the production of the steel, electricity, acetylene and diesel. The diesel is the only resource which the covers consume during their exploitation. It is used in the truck engine to carry out the covers around and to lift and lower them during drilling operation.

Research results. The open life cycles [Heijungs: 2002], i.e. the flows which have value only in one column of Tables 1 and Tables 2 are of particular interest in our case. Their positive sign shows exhaustion of natural resource and they are shown again in the column of the tables titled Exhaustion. Their negative signs show releasing of emissions in the atmosphere and the soil and are extracted in the column of the tables titled "Pollution".

The results shown in the columns "Exhaustion" and "Pollution" can be interpreted in several ways to decide which project is promoting sustainable development.

The first way to interpret the results is just by looking at them and using common sense to take the decision. This of course could be done only by environment experts which is not the case of the small company.

The second way is to summarize for each cover the total quantities of exhaustions and pollutions and on this gross bases take the decision. In this case the welded cover has total exhaustion of 107683 kg and pollution of 6263 kg. The monolith cover has total exhaustion of 153754 kg and pollution of 7431 kg. It's quite obvious the welded cover is more environment friendly than the monolith. However this way does not tell us anything about the environment influence of each component of the exhaustion and the pollution.

The third way is to send the covers to environmental agencies like EPA and use their specialist, models and software to evaluate the alternative innovative projects using their expertise and software, which obviously will be absent in the small company. However this could require additional financial resource.

Conclusions. The presented model for comparison and assessment of innovation projects for achieving sustainable development gives guidelines for the small manufacturing company to implement projects which comply with the concept of sustainable development.

On the gross bases of exhaustion and pollution the model showed that the welded cover is more environment friendly than the monolith one for its whole life cycle, though in terms of the business expense it could cost more to produce.

The model shows the direction of the company innovations for developing environment friendly products causing less harm to nature - improving the recycling of the input materials, reduction of the atmospheric and soil waste, using of non-renewable resources, etc.

Though the model is quite simple, it requires quite an effort from the small manufacturing company (which usually have one to several engineers with a lot of knowledge of design and manufacturing and none of environment) to gather all data and make the necessary calculations. The model is applied only to the two covers, but a gear box is much more complicated machine with a lot of parts. Even if the company is capable of doing all that analysis for the parts it makes, there are a lot of vendor parts over which the company does not have environmental control. One can find all data for a bearing in a catalogue except how its production and usage influences the environment.

The only way to achieve the concept of sustainable development in the small business environment is to make the small companies part of a large international network of environmental knowledge-based resources where the key concept will be "teamwork for sustainable development".

Table 1. **Material flows for production of 10 pieces welded cover for 10 years life cycle**

	Designation	Dimension	Welded cover prod	Steel production	Iore extraction	Electricity prod	Coal production	Acetylen production	Lime production	Oxygen production	Cover usage	Oil processing	Oil production	Weld consum prod	Exhaustion	Polution
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
W1	Cover sale	kg	-2660								2660					
W2	Used steel	kg	5580	-5580												
W3	Used electricity	kWh	5.72			-5.72										
W4	Used acetylene	kg	12					-12								
W5	Used oxygene	kg	229							-229						
W6	Used ore	kg		273.4	-273.4											
W7	Used coal for steel production	kg		186			-186									
W8	Used lime for steel production	kg		70					-70							
W9	Used electricity for steel production	kWh		2453.3		-2453.3										
W10	Solid waste from steel production	kg		1172												1172
W11	Gaseous waste from steel production	kg		551												551
W12	Used coal for electricity production	kg				1676.6	-1676.6									
W13	Solid waste from electricity production	kg				168										168
W14	Used electricity for oxygen production	kwh				-233.6				-233.6						
W15	Used electricity for acetylene production	kWh				-6.6		6.6								
W16	Waste from acetylene production	kg						60								60
W17	Atmospheric emissions from electr prod	kg				4312										4312
W18	Recycled covers aftre usage	kg		2660							-2660					
W19	Recycled waste from cover production	kg	-2920	2920												
W20	Used electricity for ore production	kWh			5.47	-5.47										
W21	Used electricity for coal production	kWh				-48.38	48.38									
W22	Used electricity for lime production	kWh				-0.018			0.018							
W23	Used electricity for oil rpoduction	kWh				-2757							2757			
W24	Used electricity for oil processing	kg				-2872						2872				
W25	Ore production	kg			-273										273	
W26	Coal production	kg					-1887								1887	
W27	Lime production	kg							-157	-938					157	
W28	Oxygen production	kg													938	
W29	Oil production	kg											-104433		104433	
W30	Used lime for carbide production	kg						87	-87							
W31	Used coal for carbide production	kg						24								
W32	Used oxygen for steel production	kg		709						-709						
W33	Used oil for diesel production	kg										104433	-104433			
W34	Used diesel during cover cover exploitation	kg									46622	-46622				
W35	Used steel for weld consumables prod	kg		-3.54										3.54		
W36	Used welding consumables - steel	kg		3.54										-3.54		
W37	Used electricity for welding	kWh	83			-83										
														Total:	107688	6263

Table 2. **Material flows for production of 10 pieces monolith cover for 10 years life cycle**

	Designation	Dimension	Welded cover prod	Steel production	Ore extraction	Electricity prod	Coal production	Acetylen production	Lime production	Oxygen production	Cover usage	Oil processing	Oil production	Exhaustion	Polution
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
M1	Cover sale	kg	-3820								3820				
M2	Used steel	kg	5890	-5890											
M3	Used electricity	kWh	7			-7.29									
M4	Used acetylene	kg	8					-8							
M5	Used oxygene	kg	140							-140					
M6	Used ore	kg		289	-289										
M7	Used coal for steel production	kg		196			-196								
M8	Used lime for steel production	kg		74					-74						
M9	Used electricity for steel production	kWh		2589		-2589									
M10	Solid waste from steel production	kg		1237											1237
M11	Gaseous waste from steel production	kg		582											582
M12	Used coal for electricity production	kg				2159	-2159								
M13	Solid waste from electricity production	kg				216									21
M14	Used electricity for oxygen production	kwh				-143				143					
M15	Used electricity for acetylene production	kWh				-4.3		4.3							
M16	Waste from acetylene production	kg						39							39
M17	Atmospheric emissions from electr prod	kg				5552									5552
M18	Recycled covers aftre usage	kg		3820							-3820				
M19	Recycled waste from cover production	kg	-2070	2070											
M20	Used electricity for ore production	kWh			5.77	-5.77									
M21	Used electricity for coal production	kWh				-62.21	62.21								
M22	Used electricity for lime production	kWh				-0.019			0.019						
M23	Used electricity for oil rpoduction	kWh				-3962							3962		
M24	Used electricity for oil processing	kg				-4127						2872			
M25	Ore production	kg			-289									289	
M26	Coal production	kg					-2371							2371	
M27	Lime production	kg							-130					130	
M28	Oxygen production	kg								-888				888	
M29	Oil production	kg											-150076	150076	
M30	Used lime for carbide production	kg						56	-56						
M31	Used coal for carbide production	kg					15.6	15.6	15.6						
M32	Used oxygen for steel production	kg		748						-748					
M33	Used oil for diesel production	kg										150076	-104433		
M34	Used diesel during cover cover exploitation	kg									66998	-66998			
													Total:	153754	7431

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